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The Truffle and Its Cultivation in France

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Abstract: Truffle production in France reached its peak at the turn of the 19th to 20th century, benefiting from the over-population of the countryside and the destruction of European vineyards by Phylloxera around 1870 - 1880. The two World Wars with their sociological and ecological consequences marked the start of the decline in production which motivated in turn the efforts to revive it at the start of the seventies. Ecological factors, including soil, climate and the quality of the environment made it possible to determine criteria for the cultivation of-principally-*Tuber melanosporum* in calcareous regions with a Mediterranean climate. Truffle cultivation has evolved since its invention at the beginning of the 19th century; initially very empirical, it went through a phase of development based on a model of arboriculture of mycorrhized plants; finally returning to more ecologically-based concepts at the end of the 20th century. The choice of the most appropriate method of truffle cultivation is mainly a function of the pressure due to contamination by other species of *Tuber* present in the environment. The prospects of extending truffle cultivation in France depend at the same time on scientific research, experiments on cultivation techniques, plantations with grants from local authorities, technical support and training of truffle-growers. The latter are aware that they hold in their hands an historical, sociological, gastronomic and economic heritage to enhance, faced with the initiatives launched in other European countries and the entire world.

Key words: Mycorrhized plants; *Tuber melanosporum* Vitt.; *Tuber brumale* Vitt.; Truffle arboriculture; Chalk grassland; Biodiversity

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1 The historical and geographical context of the evolution of Black Truffle production

The history of the Truffle shows that it went through a period of abundance at the turn of the 19th - 20th centuries. According to Chatin, in 1892 the Black Truffle harvest in France, covering more than 40 départements, reached a record production of 2 000 tonnes. Three-quarters of this production came from the following départements:

Vaucluse	470 tonnes
Basses-Alpes (Alpes de Haute-Provence)	380 tonnes
Lot or Quercy	360 tonnes
Dr me in Provence	180 tonnes
Dordogne or Périgord	160 tonnes

The peak production probably occurred at the start of the 20th century in the South-West. Nowadays, in the best cases French production reaches around a hundred tonnes (in the Winter of 1977 - 8), and in the worst about 10 (Winter 2003 - 4); the average is about 30 - 40 tonnes. The main producing départements are the Vaucluse, the Dr me, the Lot, the Var, the Alpes de Haute-Provence, the Gard and the Dordogne.

The end of periods of famine from the start of the 19th century on led to conditions of over-population in the countryside in the middle of the century. Wood-clearing, favoured by the new Freedom acquired following the French Revolution; as well as the need to nourish a very large rural population, contributed to land clearance in many French regions. This created particularly favourable conditions for *Tuber melanosporum*: a fungus of open spaces. The destruction of French and European vineyards by Phylloxera in about 1880 added yet more new, favourable conditions for truffles. For example, at the moment when Phylloxera arrived, the Lot department had almost 80, 000 hectares of vineyards, compared to 5000 now. These vineyards covered the causses and limestone plateaux. Nu-

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merous ruined wine-producers, who had often noticed the formation of natural truffle-grounds in their vineyards linked to the presence of bordering oaks, replanted their fields with downy oaks (*Quercus pubescens* Willd .) . This reorientation was crowned with success and many properties on the causses of the Lot and the Périgord made their fortunes .

The decline started with the First World War, since during 5 years the maintenance of truffle grounds was neglected in favour of growing food products . The rural exodus, coupled with the haemorrhage of the countryside population resulting from the Great War, led to a demographic situation which discouraged the renewal of truffle plantations . After the Second World War, radical changes in agricultural methods, which altered from being purely nutritive to production-oriented or industrial, accentuated the decline in production . Production methods changed and with them social attitudes and economic and technical practices . People lost the habit of planting truffle-producing trees-in particular because annual production was unreliable because of unpredictable droughts . Repaying bank loan instalments wasn't really compatible with the fluctuating income from truffles .

The mechanisation of agricultural work extended to truffles, whose plantations were considered as truffle orchards (Fig.1) . Free-range farming disappeared little by little on chalk grassland and juniper moors; woodland undergrowth was invaded by brushwood following the abandonment of traditional practices such as gathering leaf litter or making faggots to heat bread ovens . The habit of trimming oaks to feed flocks of sheep at the end of summer fell into disuse . The landscape progressively changed, creating environmental conditions inauspicious for the formation of natural truffle-grounds and changing the dominant position that the Black Truffle had on open land at the beginning of the 20th century . These combined factors led to a loss of the power or ' virulence ' of the truffle: a phenomenon now identified and studied, in particular at the truffle experimental station at Cahors-Le Montat .

It was only from the start of the seventies on that the revival of truffle cultivation took place under the impetus of pioneers such as Sylvain Floirat, Jean Rebière and Jean-Baptiste Champagnac in the South-West; Louis Fioc, Louis Signoret and René Gleyze in the South-East . Jean Grente, Jacques Delmas, Nicole Poitou and Gérard Chevalier, researchers at the INRA (National Agronomic Research Institute) took part in this revival through their scientific work, assisted also by the Italians scientists . Mycorrhized plants, marketed since 1974, should have encouraged renewed production . Unfortunately, in wooded environments they fell victim to contamination by other fungal species equally capable of infecting or mycorrhizing the roots of these young truffle-producing plants . Nowadays it seems likely that the solution will come from better management of truffle environments to control this contamination and favour the potential of *Tuber melanosporum* .

Fig.1 Mechanisation of agricultural work in truffle plantation (Rocamadour, Lot, France)

2 Résumé of truffle ecology in France

The Black Truffle *Tuber melanosporum* seeks environmental conditions suitable for its xero-thermo-calciphile ecological requirements: that is to say dry (xero-) and hot (thermo-) Mediterranean climates with limestone soil (calciphile) .

A knowledge of truffle-bearing soils is important because truffles are fungi which need calcareous soil with the correct qualities of drainage, aeration and biological activity (earthworms, insects etc) . Classical soil analysis is an essential tool for understanding these soils, which must be completed by an in-depth study, usually carried out in a pedological trench (Fig.2) .

Fig.2 Typical truffle producing soil (Lacave, Lot, France)

The average agronomic qualities of a truffle-bearing soil are generally as follows:

- Balanced texture: clay, silt and sand in equal proportions (sandy soils are more propitious than non-stony clayey ones).
- Limestone: 1% to 70%
- Exchangeable calcium: 0.6% to 1%, 6%
- Water pH: 7.8 to 8.3
- Organic matter: 3% to 6% on average. In the South-East and on sandy soil the content may be lower; in the South-West, higher on clayey soil.
- C N (defines the evolution of the organic matter): 8 to 12 in general.
- Nitrogen (N): 1‰ to 3‰
- Total phosphorus: 1‰ to 3‰ (the value of assimilable phosphorus in calcareous soil is not a good indicator for truffles).
- Assimilable potassium (K_2O): 0.1‰ to 0.3‰
- Assimilable magnesium (MgO): 0.1‰ to 0.5‰

Calcareous geological formations of various Epochs produced the truffle-bearing soils found in France. Amongst these formations, the calcareous of the Secondary Era have an important place, particularly those of the Jurassic and Cretaceous Epochs. Excellent truffle-bearing soils exist also on the Tertiary (Oligocene and Eocene) and Quaternary alluvia. The nature of these sediments governs that of the soil.

Truffle-producing soils are classified into three principal pedological types: rendzinas, brown calcareous soils and brown calcic soils. According to the new classification on which the AFES (French Soil Study Association) is working, the rendzinas are named 'Rendosols' ('Rendisols' for the calcic ones); the brown calcareous soils are 'Calcosols' and brown calcic soils 'Calcisols'. Other types are also truffle-producing: 'lithosols'① and 'colluviosols'②, sites of natural truffle-grounds with no real possibility of cultivation with modern tools; as well as 'fluviosols'③, especially the length of the Rhone valley.

The climate is also a decisive factor for truffle production which needs to be evaluated according the distribution of its rainfall and temperature variations during the truffle's growth cycle. *Tuber melanosporum's* climatic requirements can be summarised by the following four points:

- relatively damp and warm Springs with no late frosts, so as to encourage the activation of the mycelium and the naissance of truffles
- hot Summers punctuated with rainstorms which ensure good development of the truffles
- generally damp Autumns without early frosts which destroy the truffles
- Winters without heavy frosts lasting several days, which might destroy the truffles, and moderate rainfall so as to ensure harvesting in correct soil conditions.

The altitude of south-west France's truffle grounds is generally between 100 and 400 metres. In the South-East the Mediterranean climate allows the establishment of truffle-grounds above this height. In the Hautes-Alpes, natural truffle-grounds are present up to 1500 metres on well-oriented sites (at the lower limit of the larch tree-line), while on the Larzac plateau (in the Aveyron) some exist at 800 metres in good sunny conditions.

An awareness of the whole environment completes that of the soil and climate on a regional scale. The

① Very superficial soils limited in depth by the mother rock situated at 10 cm or less from the surface.

② Soils on colluvium generally resulting from earth sliding down a slope.

③ Soils on recent fluvial alluvium.

types of vegetation, which provide information on both the soil and the climate allow us to synthesize a picture . To put it simply: the presence of chestnuts or bell heather on a parcel lets us suppose that it has an acid soil unsuitable for black truffles .

3 Truffle Cultivation

When we speak of truffle cultivation in France, we mean principally growing the Black Truffle, *Tuber melanosporum*, which was first devised at the start of the 19th century when observant country-dwellers in the South-West and South-East decided to sow acorns or plant oaks with this in mind . The cultivation of *Bourgogne truffles*, *Tuber uncinatum*, has recently taken off in the North-East of the country, since the eighties . Amongst other species which are cultivated more or less privately, there is the White Summer Truffle, *Tuber aestivum*, the Winter truffle *Tuber brumale*, and the mesenteric truffle, *Tuber mesentericum* (Fig.3) . Numerous truffle species are spontaneously present and cause problems in terms of contaminating plantations . The species the most feared on truffle cultivation land are *Tuber brumale* and *Tuber aestivum*-even if some growers tend to put them forward .

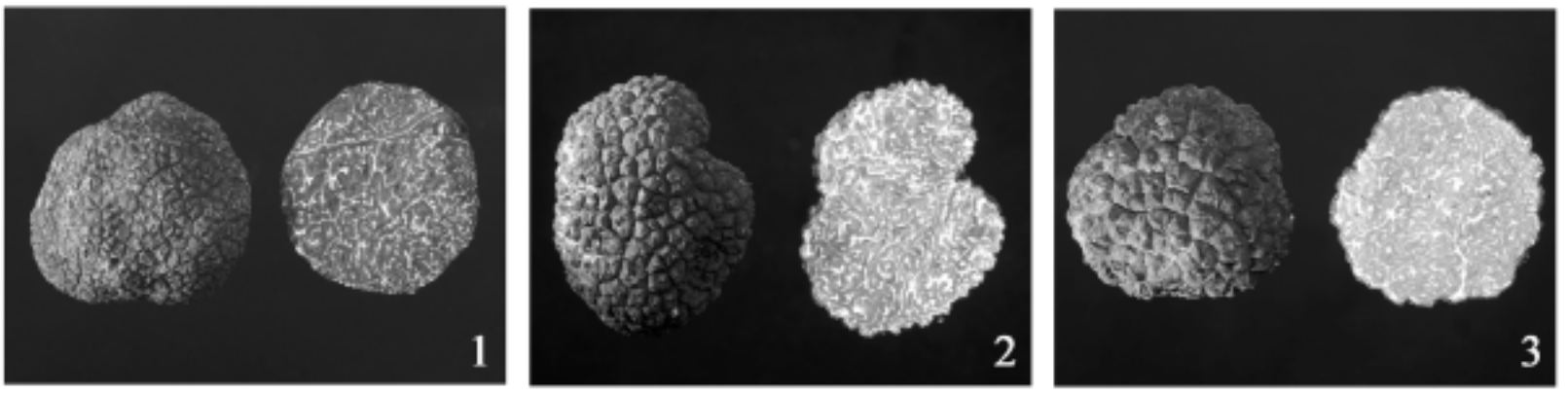

Fig.3 1 . *Tuber melanosporum* Vitt .; 2 . *Tuber uncinatum* Ch .; 3 . *Tuber aestivum* Vitt .; 4 . *Tuber mesentericum* Vitt .; 5 . *Tuber brumale* Vitt .

We can distinguish three techniques for cultivating *Tuber melanosporum*, each with their variations, which have different results depending on the environment and changing times . Truffle growers do not all agree on the best method to use; and additionally each one introduces his own nuances to his preferred approach according to his soil, his climate-and above all whether or not there is an existing family tradition of truffle cultivation .

The main methods are:

1 . the traditional method practiced before the introduction of mycorrhized plants-whose followers are becoming less and less numerous .

2 . the method of truffle arboriculture (known as ‘ Pallier ’), conceived from simple modern principles since the marketing of mycorrhized plants started in 1974 .

3 . the chalk grassland or lawn ecosystem method (named after ‘ Tanguy ’) from the nineties onwards, based on the functioning of natural truffle grounds .

3.1 The traditional method

The traditional method, invented in France two centuries ago, includes different practices which taken together are relatively consistent (Fig.4) . Even if nowadays its efficacy leaves its value debatable, this highly empirical method was behind the production of huge quantities of truffles at the end of the 19th and the beginning of the 20th centuries .

Fig.4 Plantation with traditional method (Cremps, Lot, France)

Characteristics of the traditional method:

- Production of plants from seeds (acorns) selected from good truffle-grounds (truffle-bearing oaks),
- planting in a former vineyard (in the South-West), a lavender field (in the South-East) or a parcel of ploughed land which it is difficult to cultivate profitably,
- continual working of the soil, adjusted to the age of the plants, from their planting until they start to produce; although certain truffle growers hoe young trees-and even productive adult trees-manually,
- no irrigation, but sometimes covering of good burnt areas with cut branches before really hot spells to limit evaporation,
- little or no tree pruning.

Current results of this "cultivation of trees destined to produce truffles":

- production starting increasingly later (15 to 25 years), as it is necessary to await the haphazard natural inoculation by *Tuber melanosporum* of the trees planted,
- very variable yields, with the proportion of productive trees varying from zero to more than half on the same parcel: in old centres of production where Tuber melanosporum is still firmly implanted (*Richerences* and *Aups*) yields using this method rival those of the others; but where *Tuber brumale* has progressed the results are mediocre or null,
- in general, a high percentage of sterile trees because these are mycorrhized or contaminated by fungi other than truffles.

The traditional method was the foundation of truffle cultivation in the 19th century. But now, the situation has changed: ecologically (overgrowth of the environment) and socio-economically (less labour in the countryside, and industrial agriculture as opposed to essential food production). Plantations using this method can still be seen in former producing regions, but fewer and fewer people practise it as the use of mycorrhized plants becomes more widespread. However it should be noted that the mycorrhized plant was invented specifically to compensate for the poor results of the traditional method; that is to say a lack of inoculum in the soils or a parallel loss of potential of *Tuber melanosporum*. It is likely that this negative situation hadn't yet appeared in the fifties and sixties and the traditional method continued to work successfully; except of course in new regions where introducing mycorrhized plants is necessary to introduce the inoculum.

3.2 Arboriculture for truffles (the 'Pallier' method)

This method was developed at the start of the seventies, following the marketing of mycorrhized plants "Agri-Truffe" in the winter of 1974-5) under a licence INRA-ANVAR (Fig.5). Jean Rebière[①] had already started to outline the method in the Périgord in the sixties-without mycorrhized plants. Raymond Pallier tried out and popularized this type of truffle cultivation at Sainte-Foy-de-Longas in the Périgord during almost 30 years.

Fig.5 Arboriculture with truffle plantation (Lalbenque, Lot, France)

① Jean Rebière published the first edition of "The Périgord Truffle" in 1967, published by Fanlac at Périgueux.

The method is practised everywhere in France, in Europe and even further afield .

Characteristics of the method:

- planting tested trees mycorrhized with *Tuber melanosporum* on a suitable calcareous soil .
- uninterrupted working of the soil (by cultivator, spring-tined cultivator or spike harrow) adapted to the age of the plants, from planting until the end of production .
- irrigation of truffle-bearing trees mainly in August and above all during the truffle production period (Fig.6) .
- harder and harder tree-pruning as growth is stimulated by irrigating the plantation, and if the planting density is high (400 to 800 plants per hectare) .
- calcareous soil enrichment to control competition by *Tuber brumale* and tests with organic fertilisers such as ‘ Fructitruf ’ .
- use of chemical weed-killers for clearing (glyphosate), removal of suckers, getting rid of parasites (slugs, Leiodes beetles etc) .

Fig.6 Irrigation in truffle plantation

Results of the method:

- early production, especially with hazelnut trees whose production starts in the 4th year,
- yields which can reasonably be expected to vary from 15 to 30 kilos per hectare after between 15 and 20 years,
- problems of contamination particularly by Tuber brumale in the South-West and increasingly in the South-East,
- long periods of labour, above all for tree-pruning which sometimes extends to lopping of branches .

3.3 Truffle cultivation in chalk grassland or lawn ecosystem (the ‘ Tanguy ’ method)

It was after the 1993 - 4 truffle season that this method was identified and standardized-almost 20 years after the beginnings of the ‘ Pallier ’ method . The person after whom the method was named, Marcel Tanguy, had purchased a small property in the Tarn-et-Garonne on which there was a roughly maintained hazelnut plantation whose trees started to produce late . The proprietor spoke widely about the success of this plantation (Fig.7) .

Fig.7 Truffle plantation in chalk grassland (Lascabanes, Lot, France)

Truffle plantations using the ‘ Tanguy ’ method which have attracted attention since 1994 are situated in the Vaucluse (at Apt), le Lot (at Miers), le Périgord (at Sainte-Alvère, Pézuls, and Saint-Pantaly d'Excideuil) and of course in the Tarn et Garonne (at Puygaillard) . Curiously, these highly productive plantations often cover less than a hectare (between 1000 and 6000 square meters for those mentioned) . It's very likely that the owners of such high-performance plantations prefer to remain behind the scenes, even if some new producers (for example at Beauvais-sur-Matha in the Charente Maritime) are willing to discuss their method and its results (Fig.8) .

Characteristics of the method:

- planting trees guaranteed to be mycorrhized with *Tuber melanosporum* truffles in soil either ploughed or grass-covered,
- working the soil or clearing around the young trees with

chemical weed-killers during the first two years to encourage the reinvigoration of the truffle-bearing plant,

- dropping the soil cultivation and chemical clearing from the 2nd or 3rd year onwards to encourage the establishment of the fungus and at the same time slowing down (or inhibiting) the growth of the mycorrhized trees,
- maintenance of the plantation by mowing the vegetation based on natural grasses (sometimes sown),
- cultivating the soil infrequently or when production has been in effect for several years (this work probably acts to encourage the growth of new, short roots likely to carry mycorrhiza),
- watering the truffle trees during the first two years to reinvigorate them, then when production has started, restarting watering with a fine spray (microsprinkling) on good burnt areas,
- possible pruning of the trees at the start to obtain an erect shape, stopped and then restarted when the truffle bearing space starts to form,
- no soil enrichment or fertiliser in particular, nor chemical clearance .

Fig.8 Truffle plantation in chalk grassland
(Castelnau-Montmiral, Tarn, France)

The results of the method:

- production starting later than with the ‘ Pallier ’ method, that is towards 10 to 12 years, due to competition from the other plants in the environment with the growth of the trees,
- little or no contamination by other fungi or species of *Tuber*,
- average yields per tree of 1 kilo, and sometimes more,
- harvesting on the surface, sensitive to frost and raiding,
- labour time less than for the ‘ Pallier ’ method,
- unknown longevity of production, as this model for truffle cultivation has only recently been used .

3.4 General thoughts on the choice of method

The results obtained in France and Europe-and above all in countries where there are no species of truffle naturally present in the environment, lead us to consider the justification for using each method; in particular those of truffle arboriculture and chalk grassland . In Australia, where *Tuber brumale* as well as all other species of *Tuber* other than melanosporum is absent, the common hazelnut seems to maintain a perpetual liaison with *Tuber melanosporum* (Manjimup, Western Australia) . In France, the same hazelnut tree has a strong affinity with *Tuber brumale*, which contaminates it in numerous regions despite a high level of mycorrhization of plants checked by the INRA and the CTIFL (Centre Technique Interprofessionnel des Fruits et Légumes-Inter-professional Technical Centre for Fruits and vegetables) . On the other hand the Downy oak (*Quercus pubescens* Willd .) and Green oak (*Quercus ilex* L .) are species perfectly adapted to *Tuber melanosporum* between whom affinity is traditionally good . This relationship is confirmed in Australia and New Zealand .

The parallel between the ‘ Tanguy ’ method of truffle cultivation in chalk grassland and the workings of natural truffle grounds in the South of France is easy to demonstrate . Natural truffle grounds develop in open spaces or clearings, especially in environments resulting from the neglect of cultivated land, when these spaces become wasteland reach ten to fifteen years of age (Fig.9) . Such natural truffle grounds correspond to a particular state or type of vegetation (Mesobromium, Xerobromium etc) during the evolution of the wasteland towards its final form (woodland) in calcareous zones . They display the characteristics of biodiversity that we attempt to develop in the most efficient grassy plantations .

To resume, truffle arboriculture appears to give noteworthy results in the absence of pressure due to contamination; whereas truffle cultivation in chalk grassland allows us to limit such contamination . Everything seems to show that in France, the choice of a method should be governed by the principle of precaution . It's a question of choosing the route which is likely to present the fewest risks; even if one can assume that these risks are very low in certain open or lightly-wooded landscapes .

Fig. 9 Natural truffle ground or natural "truffière" (Le Montat, Lot, France)

Precautionary technical procedures, faced with contamination by mycorrhizal fungi present in the environment, include three phases .

- Stage 1: consists of assuring the best possible re-establishment of the plant mycorrhized with *Tuber melanosporum* during the first year following planting, and even the second .
- Stage 2: not encouraging the growth of the mycorrhized plant, in order to avoid contamination by various fungi: creation of the natural environment preferred by the truffle is sought after during the formation of burnt areas .
- Stage 3: once the fructification of the fungus has been triggered, it's a matter of improving the quantity and quality of the production whilst maintaining its durability .

Following these stages it is possible to foresee tying up the cycle of truffle production with two further stages:

- Stage 4: the old plantation is renovated so as to give a second life to the production by opening up the environment .
- Stage 5: the old truffle wood is ripped up to provide a fresh base to the truffle plantation .

4 Future perspectives

Efforts in France to increase truffle production are directed towards plantations, research and experimentation, training truffle producers and promotion and publicization of the Black Truffle . As an example, in the South-West the general (County) Council of the Lot and the Regional Council of Midi-Pyrenees give grants for plantations as well as research and experimentation, supported also by the VINIFHLOR (Office National Interprofessionnel des Fruits, des Legumes, des Vins et de l'Horticulture-National Inter-professional Office for Fruits, Vegetables, Wine and Horticulture), the European Community and the Ministry of Agriculture and Fisheries . If we look further afield towards Spain and Italy, we realise that truffle production in the south of those countries is not subjected to contamination by *Tuber brumale*, which goes in hand with a lower potential for *Tuber melanosporum* .

French truffle producers are vigilant concerning developments in the truffle's reputation and marketing in Europe, particularly with respect to agri-tourism . Spanish producers seek to promote their truffles by creating a specific gastronomic interest which did not previously exist: black truffles were mainly exported to France . In Italy, the precious *Piedmont truffle* (*Tuber magnatum*) is used to promote cuisine related to pasta and wine; but equally to tourism, luxury and Art . The Hungarians are increasingly interested in *Tuber uncinatum* (an autumnal ecotype of *Tuber aestivum*), as is the case in Austria, England, Denmark and Sweden . Scientists in Nordic countries accumulate references to their local potential and experiment principally with cultivating *Tuber uncinatum* . They have no inhibitions about truffle cultivation and consider cultivating other species such as *Tuber borchii* or Choiromyces venosus . From a cultural point of view, the Nordics are confident in the interest that truffles will raise in a population

open to any exotic gastronomy . Truffles share with caviar their colour, delicacy and preciousness, raising them-according to theirs chefs trained in France-to the summit of excellent dishes . From an economic point of view, the stakes seem realistic and the Nordics have an entrepreneurial spirit .

The same phenomenon can be observed in the southern hemisphere . In New Zealand, ‘ gourmet tourism ’ has developed around truffles, wine, rafting and whale-watching ! The Australians cultivate top-quality products which have been part of French culture for a very long time, in particular truffles and wine . Chili and Argentina are represented at conferences centred on truffles and their cultivation . China is also interested in cultivating its own species *Tuber indicum* . All these factors are not without significance for the future of truffle cultivation in France . Good sense and prudence direct the French to appreciate the quality of their land, their culture and their traditions: that is to say the elements which give an additional inimitable and irreplaceable value to the Black Truffle . Typical truffle markets and gastronomic fairs which associate several local products with a district or regional identity, all play their part in an composite process of economic promotion (Fig.10) . Folklore probably has its part to play as well-beyond the controversies that it sometimes arouses .

Fig.10 Typical truffle market (Lalbenque, Lot, France)

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